3.0 Flow Monitoring Program

3.1 Overall Description

To fully understand the dynamics of the sewage collection system, the City adopted a comprehensive, City-wide rainfall and flow monitoring program. The program consisted of flow meters within the City's collection system and rain gauges installed throughout the City of Baltimore and Baltimore County. The meters measured depth and velocity, from which flow was calculated at five minute intervals. A comprehensive program consisting of over 350 flow monitors for a twelve-month period, extended from May 9, 2006 to May 18, 2007. The comprehensive program was designed to evaluate I/I at an average density of one meter for every 25,000 linear feet of pipe. Using wireless remote data collection, the program achieved an overall 97 percent data uptime, exceeding the 90 percent uptime required by the CD. Furthermore, the program achieved a low 9 percent inferred, or "qualified" data, meaning that on average the meters collected both a depth and a velocity measurement 91 percent of the time.

Sufficient dry and wet weather flow data was collected during the initial 12-month comprehensive program. Consequently, the network was reduced to approximately 100 meters (deemed long-term meters) in May 2007. These long-term meters will be used for continuous system assessment and model calibration, and have remained in service for over two years, exceeding the CD requirement of at least 18 months of flow monitoring under Paragraph 9.E.iii.b.

3.2 Metering Network within the Low Level Sewershed

There were 56 flow meters installed within the Low Level Sewershed. Most of these meters, 45, were installed for a 12-month period to obtain information to assist with infiltration and inflow (I/I) evaluation and model calibration. Additionally, 8 long-term meters were installed for long-term assessment of flows in the sewer system. The remaining three meters PSEAS, PSLOC, and PSMCC were installed at the Eastern Avenue, Locust Point, and McComas Point pumping stations but were not used for analysis. Table 3.2.1 lists the meters within the sewershed, their purpose, and installation history. Map 3.2.1 depicts the location of the meters, rain gauges, and ground water gauges within the sewershed. Figure 3.2.1 depicts a schematic of the monitoring network for the Low Level Sewershed.

The flow monitoring contractors performed independent depth and velocity measurements (field confirmations or calibrations) across the full range of depths during dry and wet weather conditions throughout the project duration, assessed monitor performance relative to these measurements, and made any necessary adjustments to the equipment to maximize the accuracy of the data with respect to actual conditions. A total of 310 field confirmations were scheduled and performed throughout the flow monitoring period – see Attachment 3.2.1 for details.

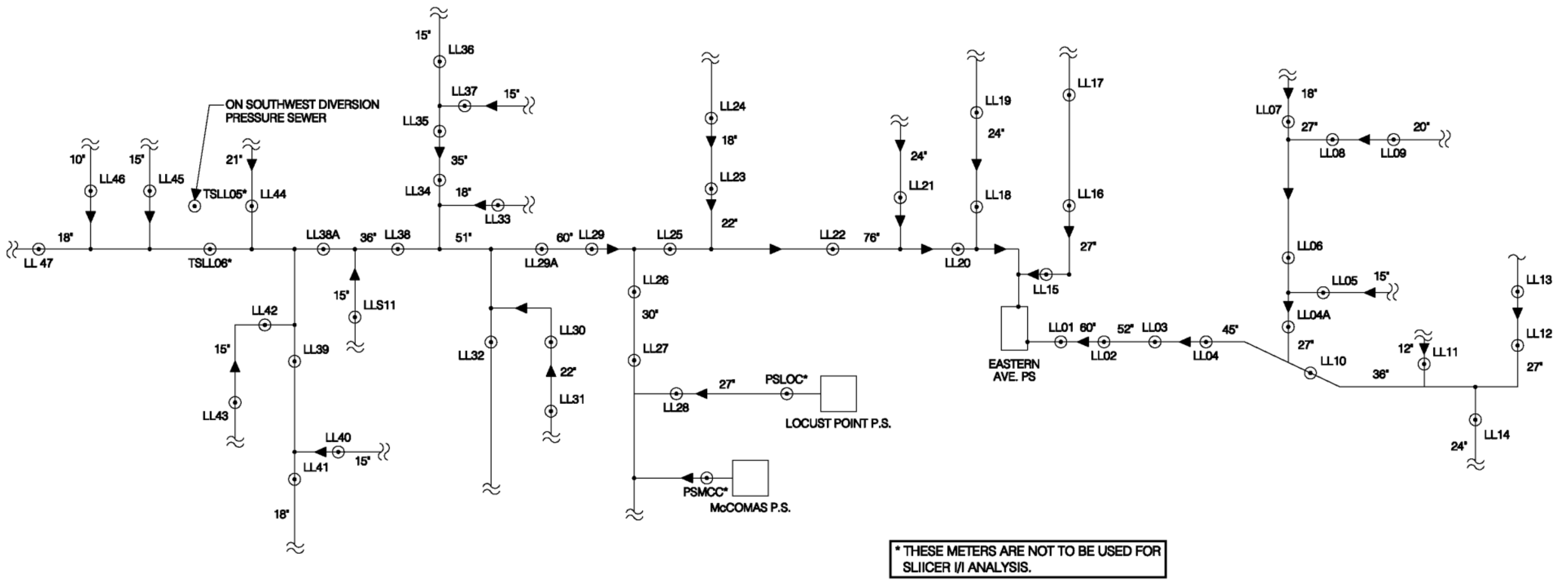

Figure 3.2.1 – Low Level Flow Monitoring Schematic

Table 3.2.1 – Low Level Flow Meter Purpose and Installation History

Meter	Purpose	Installed	Removed	Meter	Purpose	Installed	Removed
LL01	I&I/Cal	5/9/2006	Long Term	LL27	I&I/Cal	5/9/2006	5/18/2007
LL02	I&I/Cal	5/9/2006	5/18/2007	LL28	I&I/Cal	5/9/2006	5/18/2007
LL03	I&I/Cal	5/9/2006	Long Term	LL29	I&I/Cal	5/9/2006	Long Term
LL04	I&I/Cal	5/9/2006	5/18/2007	LL29A	I&I/Cal	5/9/2006	5/18/2007
LL04A	I&I/Cal	5/9/2006	5/18/2007	LL30	I&I/Cal	5/9/2006	5/18/2007
LL05	I&I/Cal	5/9/2006	5/18/2007	LL31	I&I/Cal	5/9/2006	5/18/2007
LL06	I&I/Cal	5/9/2006	5/18/2007	LL32	I&I/Cal	5/9/2006	5/18/2007
LL07	I&I/Cal	5/9/2006	5/18/2007	LL33	I&I/Cal	5/9/2006	5/18/2007
LL08	I&I/Cal	5/9/2006	5/18/2007	LL34	I&I/Cal	5/9/2006	5/18/2007
LL09	I&I/Cal	5/9/2006	5/18/2007	LL35	I&I/Cal	5/9/2006	5/18/2007
LL10	I&I/Cal	5/9/2006	5/18/2007	LL36	I&I/Cal	5/9/2006	5/18/2007
LL11	I&I/Cal	5/9/2006	5/18/2007	LL37	I&I/Cal	5/9/2006	5/18/2007
LL12	I&I/Cal	5/9/2006	5/18/2007	LL38	I&I/Cal	5/9/2006	5/18/2007
LL13	I&I/Cal	5/9/2006	Long Term	LL38A	I&I/Cal	5/9/2006	Long Term
LL14	I&I/Cal	5/9/2006	5/18/2007	LL39	I&I/Cal	5/9/2006	5/18/2007
LL15	I&I/Cal	5/9/2006	5/18/2007	LL40	I&I/Cal	5/9/2006	5/18/2007
LL16	I&I/Cal	5/9/2006	5/18/2007	LL41	I&I/Cal	5/9/2006	5/18/2007
LL17	I&I/Cal	5/9/2006	5/18/2007	LL42	I&I/Cal	5/9/2006	5/18/2007
LL18	I&I/Cal	5/9/2006	5/18/2007	LL43	I&I/Cal	5/9/2006	5/18/2007
LL19	I&I/Cal	5/9/2006	5/18/2007	LL44	I&I/Cal	5/9/2006	5/18/2007
LL20	I&I/Cal	5/9/2006	Long Term	LL45	I&I/Cal	5/9/2006	5/18/2007
LL21	I&I/Cal	5/9/2006	5/18/2007	LL46	I&I/Cal	5/9/2006	5/18/2007
LL22	I&I/Cal	5/9/2006	5/18/2007	LL47	I&I/Cal	5/9/2006	5/18/2007
LL23	I&I/Cal	5/9/2006	5/18/2007	LLS11	I&I/Cal	5/9/2006	5/18/2007
LL24	I&I/Cal	5/9/2006	5/18/2007	TSLL05	Calibration	5/9/2006	Long Term
LL25	I&I/Cal	5/9/2006	5/18/2007	TSLL06	Calibration	5/9/2006	Long Term
LL26	I&I/Cal	5/9/2006	5/18/2007				

3.3 Rainfall Measurement

The City measured the contribution from rainfall using a network of rain gauge stations with a minimum coverage of one (1) rain gauge station per ten (10) square miles, as well as data compiled by Doppler radar utilizing a minimum resolution of one (1) pixel per four (4) square kilometers. To measure the contribution from rainfall occurring in portions of the Collection System outside Baltimore City limits, the City installed additional rain gauges outside the City limits. Figure 3.3.1 on the following page presents the network of rain gauges in the City and County.

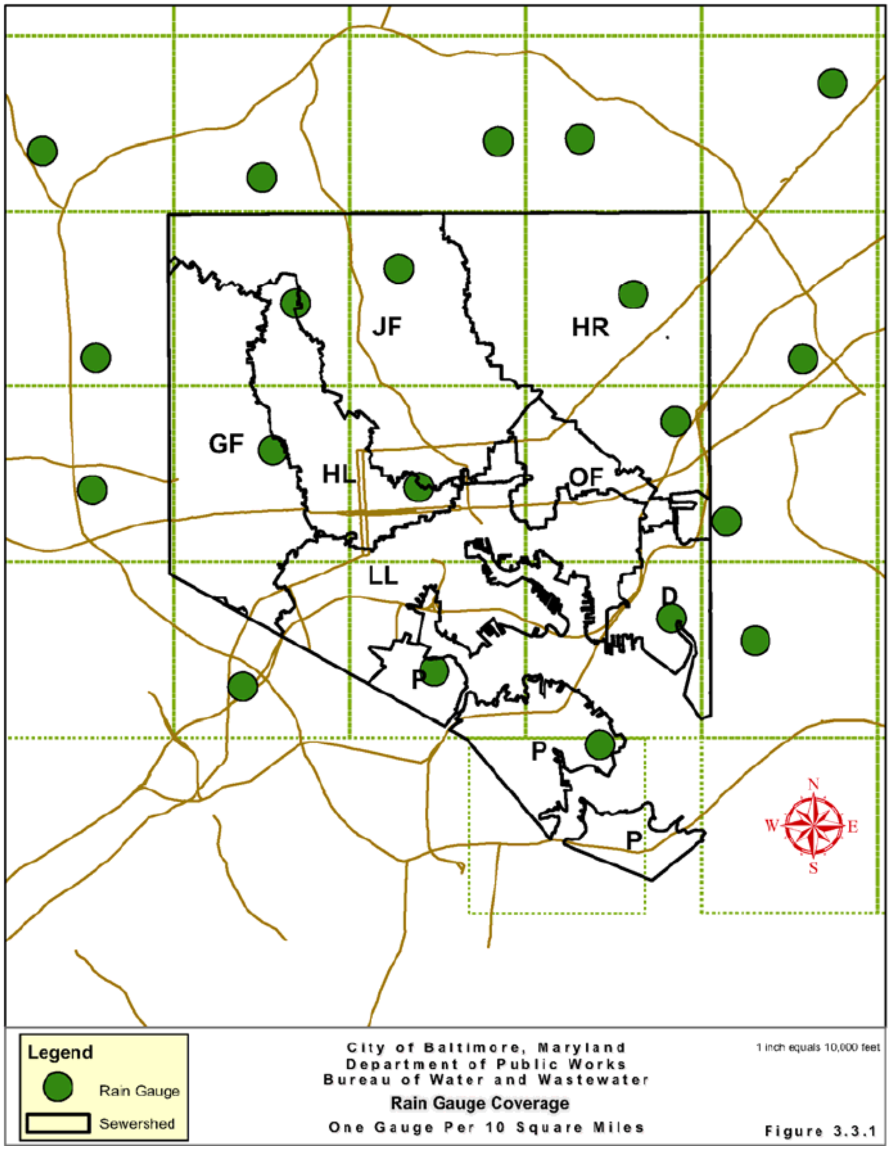

Figure 3.3.1 – Rain Gauge Network

3.4 Doppler Radar Analysis

In accordance with the requirements of the CD, the City performed Doppler Radar Rainfall Analysis in conjunction with rain gauges at a resolution of 1 gauge for every 10 square miles. The City utilized the CALAMAR software platform to process each recorded rainfall. CALAMAR uses three databases: a radar image database, a rain gauge database and a geographical database. After collecting the rain gauge network data and the radar images, CALAMAR produces a model that provides geographically accurate, integrated rainfall intensity data for any pre-defined area. The Baltimore City geographical area was divided into 1 square kilometer (about 247 acres) pixels, and for every significant rain event Doppler Radar rainfall images were generated for every pixel within the Back River and Patapsco WWTP service areas. A total of 29 storms in the Low Level Sewershed were analyzed during the primary flow monitoring period between May 2006 and May 2007 – see Table 3.4.1 for a list of storms.

Table 3.4.1 –Storms Selected for Doppler Radar Analysis

Event Start Date	Total Rainfall (inches)	Peak Intensity (in/hr)	Event Start Date)	Total Rainfall (inches	Peak Intensity (in/hr)
5/11/2006	1.52	0.84	10/27/2006	2.12	0.39
5/14/2006	0.70	0.19	11/7/2006	1.58	0.38
6/2/2006	1.07	0.67	11/16/2006	2.34	1.31
6/19/2006	0.32	0.29	11/22/2006	1.00	0.19
6/24/2006	0.82	0.40	12/22/2006	1.29	0.22
6/25/2006	6.47	1.22	12/25/2006	0.66	0.16
7/5/2006	2.61	1.27	12/31/2006	1.10	0.19
7/22/2006	0.79	0.33	1/7/2007	0.90	0.15
9/1/2006	2.77	0.37	3/1/2007	1.00	0.25
9/5/2006	2.07	0.89	3/15/2007	2.54	0.21
9/14/2006	1.52	0.17	3/23/2007	0.43	0.04
9/28/2006	0.92	0.59	4/4/2007	0.55	0.20
10/5/2006	1.77	0.19	4/11/2007	1.04	0.25
10/17/2006	1.10	0.24	4/14/2007	2.86	0.32
10/19/2006	0.57	0.16			

3.5 Data Collection, Data Processing and QA/QC Process

The City required the use of a host software support application program for remote wireless data collection of all flow meters, rain gauges, and ground water gauges. The host software maintained clock synchronization with the host system’s clock for all field equipment, thus ensuring time interval integrity for all collected data. The City required the flow monitoring service providers to employ trained data analysts experienced in processing and analyzing flow and rainfall data from sanitary sewer systems. Various analytical tools, such as hydrographs, scattergraphs, and flow balancing methods were used to verify the accuracy and precision of the flow data. Data collection was performed remotely at least twice a week and was scheduled in a manner to allow data review by a trained data analyst within 24-hours of the data collection. The analyst assessed any maintenance or monitor performance issues, and a crew was dispatched within 48 hours, and the issue resolved within 72 hours from the time the issue was identified. All measurements, adjustments, and efforts undertaken during site visits were logged in an installation/maintenance log specific to that installation

3.6 Dry Weather Analysis

This sub-section provides an overall summary of the dry weather analysis. A more complete analysis is included in Attachment 3.8.1 - The Low Level I/I Evaluation Report.

3.6.1 Base Infiltration Rates and Severity

The seasons used for the analysis in Sliicer accounted for Eastern Daylight Saving Time (DST) and Eastern Standard Time (EST). Three groups were established within the monitoring period, Summer 2006, Winter 2007 and Summer 2007, and are defined as follows:

- Summer 2006: 05/09/2006 – 10/28/2006
- Winter 2007: 10/29/2006 – 03/10/2007
- Summer 2007: 03/11/2007 – 05/18/2007

The dry day results are shown on Table 3.6.1.1 (Summer 2006), Table 3.6.1.2 (Winter 2006) and Table 3.6.1.3 (Summer 2007). As shown on these tables, the base infiltration has been normalized by inch-diameter-miles (IDM).

The basins with the highest base infiltration rates are scattered throughout the Low Level Sewershed. The basin with the highest infiltration rate normalized by IDM is LL19, which is located north of the Eastern Avenue Pumping Station. Seventeen sub-basins had infiltration values above 5,000 GPDIM, which is a common comparison level for typical sanitary sewer systems. Examination of the three seasons indicated that the group of sub-basins with the highest base infiltration in one season also had the highest base infiltration in the other two seasons. This demonstrates that the relative magnitude of base infiltration among meter basins is fairly consistent throughout the seasons. Map 3.6.1 depicts the severity of the base infiltration, normalized by IDM. The infiltration rates were divided into five different ranges, as depicted on this map.

Table 3.6.1.1 – Dry Weather Analysis (Summer 2006)

Basin	A_{gross} (acres)	A_{net} (acres)	A_{net} / A_{gross} (%)	IDM (in-dia- mile)	ADF_{gross} (MGD)	ADF_{net} (MGD)	Q_{net}/ Q_{gross} (%)	WWP_{net} (MGD)	BI_{net} (MGD)	BI Severity (gpd/ idm)	BI Rate (%)	WWP Rate (gln/l.f.)
LL19	158.3	158.3	100.0%	65.7	1.985	1.985	100.0%	0.486	1.499	22,815.8	72.5%	13.4
LL18	85.5	85.5	100.0%	44.2	3.142	1.156	35.4%	0.255	0.901	20,384.6	79.7%	11.7
LL24	75.9	75.9	100.0%	33.6	0.974	0.974	100.0%	0.348	0.627	18,660.7	67.6%	18.4
LL17	82.8	82.8	100.0%	46.8	0.847	0.847	100.0%	0.147	0.700	14,957.3	123.0%	5.1
LL34	381.3	87.5	22.9%	44.1	2.174	1.091	52.8%	0.534	0.557	12,630.4	45.2%	24.2
LL14	417.9	417.9	100.0%	39.4	0.550	0.550	100.0%	0.084	0.466	11,827.4	79.1%	4.4
LL30	136.7	75.9	55.6%	42.9	0.911	0.587	73.1%	0.116	0.470	10,955.7	58.5%	4.6
LL37	85.4	85.4	100.0%	37.9	0.487	0.487	100.0%	0.138	0.349	9,208.4	71.2%	6.1
LL21	150.3	150.3	100.0%	65.4	1.137	1.137	100.0%	0.605	0.532	8,134.6	46.6%	17.5
LL38	2,347.0	447.9	19.1%	62.9	4.417	0.572	8.7%	0.073	0.500	7,949.1	152.4%	3.3
LL23	196.0	120.2	61.3%	60.3	1.606	0.631	31.1%	0.179	0.452	7,495.9	108.1%	6.2
LL38A	2,264.5	353.9	15.6%	86.3	3.682	0.650	7.5%	0.038	0.612	7,091.5	243.8%	1.5
LL46	52.7	52.7	100.0%	13.4	0.220	0.220	100.0%	0.129	0.091	6,791.0	41.6%	14.8
LL44	190.4	190.4	100.0%	75.1	0.627	0.627	100.0%	0.122	0.505	6,724.4	73.0%	2.7
LL16	148.4	65.6	44.2%	33.4	1.275	0.428	47.2%	0.210	0.218	6,526.9	42.8%	12.5
LL27	694.0	319.3	46.0%	51.9	1.618	0.461	23.7%	0.138	0.323	6,223.5	72.6%	5.1
LLS11	82.5	82.5	100.0%	18.4	0.162	0.162	100.0%	0.056	0.106	5,760.9	107.1%	5.3
LL03/LL04/LL04A*	2,009.8	222.0	11.0%	137.9	4.901	1.333	26.2%	0.541	0.792	5,743.3	55.7%	8.5
LL42	415.6	122.4	29.4%	37.5	0.952	0.472	29.2%	0.263	0.209	5,573.3	85.7%	13.2
LL45	204.0	204.0	100.0%	32.5	0.208	0.208	100.0%	0.061	0.147	4,523.1	67.4%	3.0
LL11	102.1	102.1	100.0%	41.8	0.389	0.389	100.0%	0.211	0.179	4,282.3	51.7%	7.9
LL31	60.7	60.7	100.0%	30.4	0.325	0.325	100.0%	0.195	0.130	4,276.3	43.9%	10.4
LL08/LL09*	269.5	269.5	100.0%	68.8	0.577	0.577	100.0%	0.289	0.288	4,186.0	49.0%	7.6
LL33	83.6	83.6	100.0%	34.9	0.224	0.224	100.0%	0.078	0.146	4,183.4	75.3%	4.1
LL28	374.7	374.7	100.0%	56.4	1.157	1.157	100.0%	0.926	0.231	4,095.7	16.1%	34.3
LL07	98.9	98.9	100.0%	54.2	0.440	0.440	100.0%	0.226	0.214	3,948.3	49.9%	6.8
LL36	109.6	109.6	100.0%	48.7	0.279	0.279	100.0%	0.116	0.163	3,347.0	55.4%	4.0
LL26	811.5	117.5	14.5%	53.3	1.959	0.341	3.5%	0.165	0.176	3,302.1	255.1%	6.8
LL35	293.9	98.9	33.7%	46.5	1.083	0.317	28.9%	0.182	0.136	2,924.7	42.8%	7.1
LL40	253.1	253.1	100.0%	50.0	0.293	0.293	100.0%	0.149	0.144	2,880.0	41.1%	4.8
LL05	94.3	94.3	100.0%	31.2	0.263	0.263	100.0%	0.174	0.089	2,852.6	33.3%	8.8
LL47	282.7	282.7	100.0%	57.8	0.251	0.251	100.0%	0.093	0.158	2,733.6	45.1%	3.0
LL10	1,093.5	175.2	16.0%	83.1	1.845	0.258	23.2%	0.046	0.212	2,551.1	40.9%	1.3
LL12	398.3	197.9	49.7%	68.0	0.647	0.339	67.8%	0.195	0.144	2,117.6	27.3%	6.2
LL39	765.3	196.9	25.7%	54.0	0.774	0.217	16.9%	0.103	0.114	2,111.1	86.4%	3.7
LL32	450.4	450.4	100.0%	81.0	0.364	0.364	100.0%	0.200	0.165	2,037.0	43.4%	4.9
LL20	5,526.9	116.7	2.1%	90.5	13.162	0.753	10.1%	0.579	0.174	1,922.7	13.1%	21.4
LL41	315.3	315.3	100.0%	73.7	0.264	0.264	100.0%	0.137	0.127	1,723.2	42.2%	3.2
LL13	200.4	200.4	100.0%	50.9	0.308	0.308	100.0%	0.237	0.071	1,394.9	28.2%	8.3

Basin	A_{gross} (acres)	A_{net} (acres)	A_{net} / A_{gross} (%)	IDM (in-dia- mile)	ADF_{gross} (MGD)	ADF_{net} (MGD)	Q_{net}/ Q_{gross} (%)	WWP_{net} (MGD)	BI_{net} (MGD)	BI Severity (gpd/ idm)	BI Rate (%)	WWP Rate (gln/l.f.)
LL01/LL02*	2,222.4	212.7	9.6%	144.7	5.846	0.945	10.5%	0.745	0.200	1,382.2	31.8%	14.6
LL43	293.2	293.2	100.0%	57.6	0.480	0.480	100.0%	0.411	0.069	1,197.9	11.7%	11.5
LL06	600.0	231.6	38.6%	71.9	1.459	0.442	32.1%	0.463	0.000	0.0	0.0%	13.3
LL15	242.4	94.0	38.8%	53.0	1.503	0.228	34.9%	0.313	0.000	0.0	0.0%	10.6
LL22	5,259.9	112.7	2.1%	64.4	11.272	0.606	3.4%	0.398	0.000	0.0	0.0%	16.1
LL25/LL29*	4,951.2	185.9	3.8%	114.4	9.097	0.000	0.4%	0.117	0.000	0.0	0.0%	3.4
LL29A	3,953.8	106.9	2.7%	62.3	8.070	0.131	6.3%	0.019	0.000	0.0	0.0%	1.1

*Meter tributary areas were combined for the I/I analysis to overcome the erratic influence of the Eastern Avenue Pumping Station

Table 3.6.1.2 – Dry Weather Analysis (Winter 2007)

Basin	A_{gross} (acres)	A_{net} (acres)	A_{net} / A_{gross} (%)	IDM (in-dia- mile)	ADF_{gross} (MGD)	ADF_{net} (MGD)	Q_{net}/ Q_{gross} (%)	WWP_{net} (MGD)	BI_{net} (MGD)	BI Severity (gpd/ idm)	BI Rate (%)	WWP Rate (gln/l.f.)
LL19	158.3	158.3	100.0%	65.7	2.068	2.068	100.0%	0.432	1.636	24,901.1	82.4%	11.9
LL18	85.5	85.5	100.0%	44.2	3.199	1.131	36.8%	0.340	0.791	17,895.9	68.4%	15.5
LL34	381.3	87.5	22.9%	44.1	2.334	1.232	50.2%	0.444	0.788	17,868.5	72.2%	20.1
LL24	75.9	75.9	100.0%	33.6	0.927	0.927	100.0%	0.345	0.582	17,321.4	59.8%	18.2
LL30	136.7	75.9	55.6%	42.9	1.100	0.804	64.4%	0.192	0.611	14,242.4	104.1%	7.6
LL14	417.9	417.9	100.0%	39.4	0.589	0.589	100.0%	0.133	0.456	11,573.6	82.9%	7.0
LL20*	5,526.9	116.7	2.1%	90.5	13.162	1.325	5.7%	0.362	0.963	10,640.9	127.9%	13.4
LL37	85.4	85.4	100.0%	37.9	0.490	0.490	100.0%	0.138	0.352	9,287.6	72.3%	6.1
LL17	82.8	82.8	100.0%	46.8	0.569	0.569	100.0%	0.148	0.421	8,995.7	49.7%	5.1
LL29A	3,953.8	106.9	2.7%	62.3	8.207	0.514	1.6%	0.014	0.500	8,025.7	381.7%	0.8
LL46	52.7	52.7	100.0%	13.4	0.219	0.219	100.0%	0.112	0.107	7,985.1	48.6%	12.9
LL21	150.3	150.3	100.0%	65.4	1.142	1.142	100.0%	0.649	0.493	7,538.2	43.4%	18.8
LL44	190.4	190.4	100.0%	75.1	0.692	0.692	100.0%	0.131	0.561	7,470.0	89.5%	2.9
LL27	694.0	319.3	46.0%	51.9	1.879	0.445	28.5%	0.060	0.385	7,418.1	83.5%	2.2
LL28	374.7	374.7	100.0%	56.4	1.434	1.434	100.0%	1.072	0.363	6,436.2	31.4%	39.7
LL15	242.4	94.0	38.8%	53.0	1.657	0.579	15.2%	0.299	0.280	5,283.0	122.8%	10.2
LL03/LL04/LL04A*	2,009.8	222.0	11.0%	137.9	5.420	1.422	27.2%	0.704	0.719	5,213.9	53.9%	11.0
LL16	148.4	65.6	44.2%	33.4	1.079	0.509	33.6%	0.638	0.159	4,760.5	37.1%	37.9
LL08/LL09*	269.5	269.5	100.0%	68.8	0.588	0.588	100.0%	0.274	0.314	4,564.0	54.4%	7.2
LL45	204.0	204.0	100.0%	32.5	0.218	0.218	100.0%	0.072	0.146	4,492.3	70.2%	3.5
LL12	398.3	197.9	49.7%	68.0	0.779	0.528	52.4%	0.227	0.300	4,411.8	88.5%	7.2
LL23	196.0	120.2	61.3%	60.3	1.344	0.418	39.3%	0.153	0.264	4,378.1	41.8%	5.3
LL10	1,093.5	175.2	16.0%	83.1	2.233	0.518	14.0%	0.169	0.350	4,211.8	135.7%	4.6
LL47	282.7	282.7	100.0%	57.8	0.350	0.350	100.0%	0.113	0.238	4,117.6	94.8%	3.6
LL38	2,347.0	447.9	19.1%	62.9	3.761	0.328	12.9%	0.071	0.257	4,085.9	44.9%	3.3
LL07	98.9	98.9	100.0%	54.2	0.429	0.429	100.0%	0.216	0.213	3,929.9	48.4%	6.5
LL31	60.7	60.7	100.0%	30.4	0.296	0.296	100.0%	0.179	0.117	3,848.7	36.0%	9.6

Basin	A_{gross} (acres)	A_{net} (acres)	A_{net} / A_{gross} (%)	IDM (in-dia- mile)	ADF_{gross} (MGD)	ADF_{net} (MGD)	Q_{net}/ Q_{gross} (%)	WWP_{net} (MGD)	BI_{net} (MGD)	BI Severity (gpd/ idm)	BI Rate (%)	WWP Rate (gln/l.f.)
LL36	109.6	109.6	100.0%	48.7	0.294	0.294	100.0%	0.109	0.185	3,798.8	66.3%	3.7
LL42	415.6	122.4	29.4%	37.5	0.835	0.244	49.6%	0.106	0.138	3,680.0	29.2%	5.3
LL40	253.1	253.1	100.0%	50.0	0.350	0.350	100.0%	0.179	0.171	3,420.0	58.4%	5.8
LLS11	82.5	82.5	100.0%	18.4	0.099	0.099	100.0%	0.041	0.058	3,152.2	35.8%	3.9
LL33	83.6	83.6	100.0%	34.9	0.194	0.194	100.0%	0.086	0.108	3,094.6	48.2%	4.5
LL35	293.9	98.9	33.7%	46.5	1.102	0.318	29.3%	0.182	0.136	2,924.7	42.9%	7.1
LL11	102.1	102.1	100.0%	41.8	0.346	0.346	100.0%	0.240	0.106	2,535.9	27.2%	9.0
LL38A	2,264.5	353.9	15.6%	86.3	3.335	0.251	17.7%	0.033	0.205	2,375.4	31.5%	1.3
LL05	94.3	94.3	100.0%	31.2	0.267	0.267	100.0%	0.197	0.070	2,243.6	26.6%	10.0
LL13	200.4	200.4	100.0%	50.9	0.252	0.252	100.0%	0.146	0.106	2,082.5	34.4%	5.1
LL43	293.2	293.2	100.0%	57.6	0.592	0.592	100.0%	0.479	0.113	1,961.8	23.5%	13.4
LL32	450.4	450.4	100.0%	81.0	0.380	0.380	100.0%	0.232	0.148	1,827.2	40.7%	5.7
LL41	315.3	315.3	100.0%	73.7	0.301	0.301	100.0%	0.167	0.134	1,818.2	50.8%	3.9
LL01/LL02*	2,222.4	212.7	9.6%	144.7	6.004	0.628	16.2%	0.347	0.237	1,637.9	25.1%	6.8
LL06	600.0	231.6	38.6%	71.9	1.497	0.480	30.3%	0.428	0.052	723.2	11.8%	12.3
LL39	765.3	196.9	25.7%	54.0	0.783	0.132	28.0%	0.102	0.030	555.6	13.8%	3.6
LL26	811.5	117.5	14.5%	53.3	1.948	0.069	17.4%	0.045	0.024	450.3	7.0%	1.9
LL22	5,259.9	112.7	2.1%	64.4	10.695	0.368	5.4%	0.575	0.000	0.0	0.0%	23.2
LL25/LL29*	4,951.2	185.9	3.8%	114.4	9.161	0.035	0.0%	0.139	0.000	0.0	--	4.1

*Meter tributary areas were combined for the I/I analysis to overcome the erratic influence of the Eastern Avenue Pumping Station

Table 3.6.1.3 – Dry Weather Analysis (Summer 2007)

Basin	A_{gross} (acres)	A_{net} (acres)	A_{net} / A_{gross} (%)	IDM (in-dia- mile)	ADF_{gross} (MGD)	ADF_{net} (MGD)	Q_{net}/ Q_{gross} (%)	WWP_{net} (MGD)	BI_{net} (MGD)	BI Severity (gpd/ idm)	BI Rate (%)	WWP Rate (gln/l.f.)
LL19	158.3	158.3	100.0%	65.7	2.054	2.054	100.0%	0.440	1.614	24,566.2	78.6%	12.1
LL24	75.9	75.9	100.0%	33.6	0.927	0.927	100.0%	0.324	0.603	17,946.4	65.0%	17.1
LL23	196.0	120.2	61.3%	60.3	2.248	1.321	58.8%	0.305	1.016	16,849.1	76.9%	10.5
LL18	85.5	85.5	100.0%	44.2	3.062	1.008	32.9%	0.313	0.695	15,724.0	68.9%	14.3
LL34	381.3	87.5	22.9%	44.1	2.341	1.160	49.6%	0.527	0.633	14,353.7	54.6%	23.9
LL30	136.7	75.9	55.6%	42.9	1.101	0.807	73.3%	0.202	0.605	14,102.6	75.0%	8.0
LL28	374.7	374.7	100.0%	56.4	1.308	1.308	100.0%	0.650	0.658	11,666.7	50.3%	24.1
LL37	85.4	85.4	100.0%	37.9	0.560	0.560	100.0%	0.149	0.411	10,844.3	73.4%	6.6
LL14	417.9	417.9	100.0%	39.4	0.533	0.533	100.0%	0.128	0.405	10,279.2	76.0%	6.8
LL16	148.4	65.6	44.2%	33.4	1.003	0.576	57.4%	0.236	0.340	10,179.6	59.0%	14.0
LL01/LL02*	2,222.4	212.7	9.6%	144.7	7.092	1.622	22.9%	0.446	1.176	8,127.2	72.5%	8.7
LL44	190.4	190.4	100.0%	75.1	0.669	0.669	100.0%	0.114	0.555	7,390.1	83.0%	2.5
LL46	52.7	52.7	100.0%	13.4	0.211	0.211	100.0%	0.112	0.099	7,388.1	46.9%	12.9
LL38	2,347.0	447.9	19.1%	62.9	4.139	0.612	14.8%	0.149	0.463	7,360.9	75.7%	6.8
LLS11	82.5	82.5	100.0%	18.4	0.164	0.164	100.0%	0.031	0.133	7,228.3	81.1%	2.9

Basin	A_{gross} (acres)	A_{net} (acres)	A_{net} / A_{gross} (%)	IDM (in-dia- mile)	ADF_{gross} (MGD)	ADF_{net} (MGD)	Q_{net}/ Q_{gross} (%)	WWP_{net} (MGD)	BI_{net} (MGD)	BI Severity (gpd/ idm)	BI Rate (%)	WWP Rate (gln/l.f.)
LL21	150.3	150.3	100.0%	65.4	1.123	1.123	100.0%	0.652	0.471	7,201.8	41.9%	18.9
LL17	82.8	82.8	100.0%	46.8	0.427	0.427	100.0%	0.101	0.326	6,965.8	76.3%	3.5
LL15	242.4	94.0	38.8%	53.0	1.714	0.710	41.4%	0.381	0.329	6,207.5	46.3%	12.9
LL42	415.6	122.4	29.4%	37.5	0.934	0.360	38.5%	0.131	0.229	6,106.7	63.6%	6.6
LL29A	3,953.8	106.9	2.7%	62.3	8.593	0.419	4.9%	0.042	0.377	6,051.4	90.0%	2.5
LL45	204.0	204.0	100.0%	32.5	0.248	0.248	100.0%	0.059	0.189	5,815.4	76.2%	2.9
LL10	1,093.5	175.2	16.0%	83.1	2.361	0.600	25.4%	0.144	0.456	5,487.4	76.0%	3.9
LL36	109.6	109.6	100.0%	48.7	0.366	0.366	100.0%	0.112	0.254	5,215.6	69.4%	3.8
LL12	398.3	197.9	49.7%	68.0	0.873	0.489	56.0%	0.139	0.350	5,147.1	71.6%	4.4
LL03/LL04/LL04A*	2,009.8	222.0	11.0%	137.9	5.490	1.248	22.7%	0.607	0.641	4,648.3	51.4%	9.5
LL20	5,526.9	116.7	2.1%	90.5	13.162	0.895	6.8%	0.509	0.386	4,265.2	43.1%	18.8
LL27	694.0	319.3	46.0%	51.9	1.740	0.431	24.8%	0.220	0.211	4,065.5	49.0%	8.1
LL33	83.6	83.6	100.0%	34.9	0.233	0.233	100.0%	0.095	0.138	3,954.2	59.2%	5.0
LL31	60.7	60.7	100.0%	30.4	0.293	0.293	100.0%	0.174	0.119	3,914.5	40.6%	9.3
LL40	253.1	253.1	100.0%	50.0	0.372	0.372	100.0%	0.186	0.186	3,720.0	50.0%	6.0
LL47	282.7	282.7	100.0%	57.8	0.311	0.311	100.0%	0.113	0.198	3,425.6	63.7%	3.6
LL07	98.9	98.9	100.0%	54.2	0.400	0.400	100.0%	0.216	0.184	3,394.8	46.0%	6.5
LL11	102.1	102.1	100.0%	41.8	0.355	0.355	100.0%	0.220	0.135	3,229.7	38.0%	8.2
LL08/LL09*	269.5	269.5	100.0%	68.8	0.422	0.422	100.0%	0.216	0.206	2,994.2	48.8%	5.7
LL06	600.0	231.6	38.6%	71.9	1.604	0.782	48.8%	0.598	0.184	2,559.1	23.5%	17.1
LL32	450.4	450.4	100.0%	81.0	0.376	0.376	100.0%	0.182	0.194	2,395.1	51.6%	4.4
LL05	94.3	94.3	100.0%	31.2	0.277	0.277	100.0%	0.203	0.074	2,371.8	26.7%	10.3
LL13	200.4	200.4	100.0%	50.9	0.384	0.384	100.0%	0.273	0.111	2,180.7	28.9%	9.6
LL41	315.3	315.3	100.0%	73.7	0.303	0.303	100.0%	0.159	0.144	1,953.9	47.5%	3.7
LL43	293.2	293.2	100.0%	57.6	0.574	0.574	100.0%	0.466	0.108	1,875.0	18.8%	13.0
LL38A	2,264.5	353.9	15.6%	86.3	3.364	0.161	4.8%	0.022	0.139	1,610.7	86.3%	0.9
LL35	293.9	98.9	33.7%	46.5	1.180	0.255	21.6%	0.181	0.074	1,591.4	29.0%	7.1
LL39	765.3	196.9	25.7%	54.0	0.852	0.177	20.8%	0.095	0.082	1,518.5	46.3%	3.4
LL26	811.5	117.5	14.5%	53.3	1.819	0.092	5.1%	0.040	0.053	994.4	57.6%	1.7
LL22	5,259.9	112.7	2.1%	64.4	11.291	0.185	1.6%	0.463	0.000	0.0	0.0%	18.7
LL25/LL29*	4,951.2	185.9	3.8%	114.4	9.210	0.003	0.0%	0.118	0.000	0.0	0.0%	3.5

*Meter tributary areas were combined for the I/I analysis to overcome the erratic influence of the Eastern Avenue Pumping Station

3.6.2 Correlation with Completed CCTV and Manhole Inspections

There appears to be little or no correlation between the rate of base infiltration and the manhole leaks reported from the manhole inspections. For example, while the LL25/LL29 sub-basin had the lowest rate of base infiltration, 41 percent of manholes in this sub-basin had at least one infiltration defect reported. Also, while the LL19 sub-basin had the highest rate of base infiltration, 39 percent of manholes in this sub-basin had at least one infiltration defect reported. In both LL25/LL29 and LL19, 6 percent of manholes were reported to have leaks in two different areas of the manhole. There also appears to be a lack of correlation between the evidence of infiltration from the CCTV inspections and the rate of base infiltration. While the LL25/LL29 sub-basin had the lowest base infiltration and 10 percent of pipes in this sub-basin had evidence of infiltration from the CCTV inspections, LL18, which has the second highest rate of base infiltration, also had only 10 percent of pipes showing evidence of infiltration. The other sub-basins occasionally showed a link between the base infiltration and evidence of infiltration from the CCTV inspections in that a sub-basin with high base infiltration also had a high percentage of pipes with infiltration, but there was not enough consistency to assume a correlation. This is not unusual and could be attributed to the fact that the majority of I/I sources are typically located in the private sector. A number of studies throughout the nation indicate that as much as 75 percent of I/I sources are located on private property or outside the view of the camera.

3.6.3 Influence of Groundwater Table on Infiltration Rates

To assess the impact of the groundwater table on infiltration rates, a comparison of infiltration rates from summer versus winter was completed, and in general, but not for all basins, the winter infiltration rates are higher than the summer rates, indicating that as the ground water table gets higher, so do the infiltration rates. The groundwater table level is affected by climatic changes and by the amount of groundwater used by vegetation.

3.6.4 Base Infiltration from Baltimore County

The Low Level Sewershed is not impacted by flows from Baltimore County.

3.7 Wet Weather Analysis

This sub-section provides an overall summary of the wet weather analysis. A more complete analysis is included in Attachment 3.8.1 – The Low Level I/I Evaluation Report.

Table 3.7.1 – Wet Weather Analysis

Basin	RDII (gal/l.f. - in)	Capture Coefficient (R %)	RDII Ranking	Capture Coefficient (R) Ranking
LL01/LL02*	59.2	52.4	3	2
LL03/LL04/LL04A*	16.6	17.6	10	7
LL05	9.1	7.0	23	25
LL06	12.9	7.2	13	24
LL07	6.4	7.9	36	18
LL08/LL09*	4.7	2.4	42	40
LL10	9.5	7.3	21	23
LL11	6.7	6.5	34	26
LL12	8.8	5.1	24	32
LL13	4.9	2.6	41	39
LL14	13.4	2.2	12	42
LL15	11.1	12.8	18	9
LL16	7.8	7.3	28	22
LL17	7.3	9.3	32	11
LL18	24.3	23.0	9	5
LL19	10.1	8.5	20	14
LL20	365.3	312.4	1	1
LL21	6.6	5.6	35	29
LL22	54.0	43.8	4	4
LL23	2.5	2.2	46	43
LL24	3.6	3.3	45	35
LL25/LL29*	68.6	46.4	2	3
LL26	11.2	8.5	17	15
LL27	7.5	2.4	31	41
LL28	28.2	7.5	8	21
LL29A	37.5	21.4	5	6
LL30	11.3	13.9	16	8
LL31	7.9	9.0	27	12
LL32	5.0	1.7	40	46
LL33	5.1	4.3	39	33
LL34	8.4	7.8	25	19
LL35	5.6	5.3	38	30
LL36	12.5	12.3	15	10
LL37	8.4	8.2	26	16
LL38	32.5	5.8	6	28
LL38A	31.1	8.9	7	13
LL39	6.1	3.2	37	36
LL40	9.3	4.2	22	34
LL41	4.1	2.1	43	44
LL42	12.7	7.6	14	20
LL43	3.9	1.8	44	45
LL44	6.8	5.9	33	27
LL45	7.7	2.8	29	38
LL46	13.5	8.2	11	17
LL47	7.7	3.1	30	37
LLS11	10.8	5.1	19	31

3.7.1 Observed Peak Flows

Data from the flow metering provide the peak flows from each storm for each meter. These data are shown on the hydrographs provided in Attachment 3.8.1.

3.7.2 Rain Dependent I/I (RDII) Rates and Severity

The RDII has been normalized by linear feet of pipe and inches of rainfall. These results are shown on Table 3.7.1 and on Map 3.7.1. The normalized values were used to rank the RDII severity throughout the sewershed. The basin with the greatest RDII severity is LL20, however the results from this basin are suspicious since the capture coefficient for the basin was greater than 100%. This may be due to the possibility that the observed rainfall data collected for certain storms were less than the actual rainfall that fell on the sub-basin. Thus, lower rain values in the denominator of the normalized calculation led to higher than expected capture coefficient values. Another potential reason for the high capture coefficient values may be the inaccuracy of the flow data at this site. Upon close inspection of the flow patterns at LL20, it was observed that the relative magnitude of flows decreased considerably from 2006 to 2007. In addition, this meter is located just upstream of the Eastern Avenue Pumping Station, possibly leading to inaccurate flow metering results. Because this meter is upstream of the pumping station, it was affected by the wet well level and was almost always in backwater. Figure 3.7.2 shows the scattergraph of the flow meter data in this area. The circular pattern is typically a result of an upstream pumping station. Inspection of the next upstream meter, LL22, revealed more consistent flow behavior, further supporting the suspicion of the data at LL20. Thus, the high flows recorded at LL20 in 2006 may have skewed the RDII calculation, leading to the higher than expected capture coefficient. For this reason, the flows from the Summer 2007 season were used to estimate RDII in the LL20 sewershed.

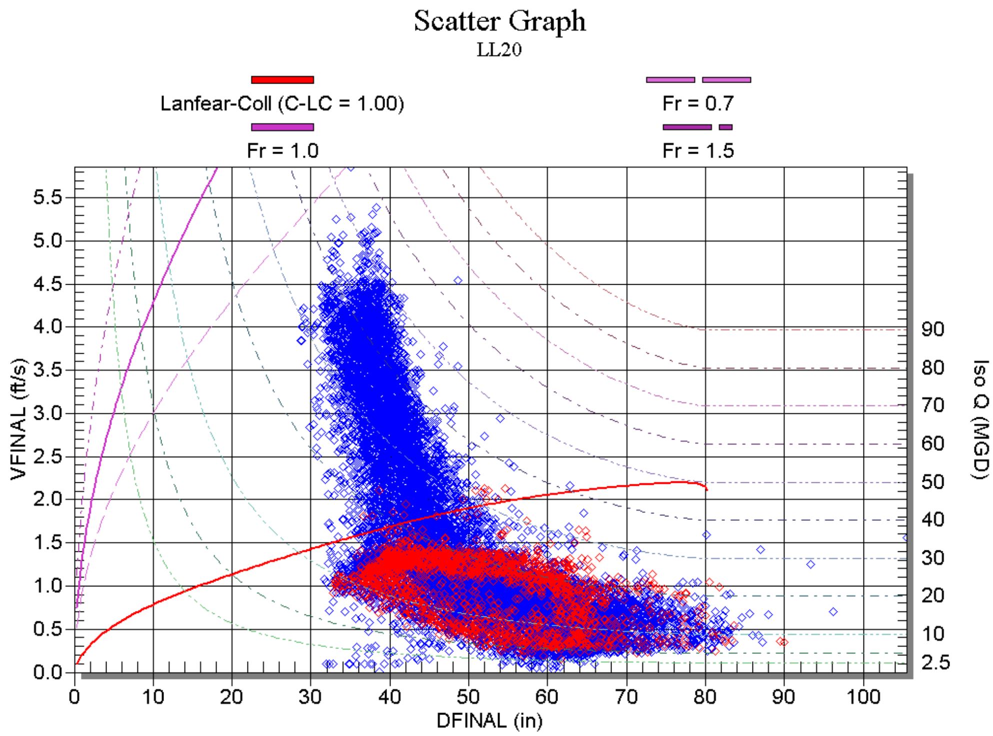

Figure 3.7.2 – LL20 Scattergraph

A total of 20 basins have a normalized RDII value greater than 10 gallons per linear foot per inch of rainfall. The majority of these basins are located in the vicinity of the Eastern Avenue Pumping Station, while the basins with normalized RDII values less than 10 are generally located towards the extremities of the Low Level sewershed.

A review of the scattergraph plots included in Attachment 3.8.1 shows evidence of surcharge, primarily located in the Gwynn's Falls Area and Eastern Avenue Pumping Station. Surcharge and backwater exist in the pipes both upstream and downstream of the Eastern Avenue Pumping Station (EAPS). There were other isolated occurrences of surcharge and SSOs in the extremities of the Low Level Sewershed. Throughout the sewershed, there were also regular occurrences of sediment in the pipe which impede the flow and cause misleading results.

The occurrence of backwater and surcharge in LL01, LL02, LL03, LL04, LL04A, LL10, LL15, LL18, LL20, LL22, LL23, LL24, LL25 and LL29 was primarily a result of the operations at the Eastern Avenue Pumping Station. The data that were collected when the meters were installed indicate that in most of these locations, there were significant accumulations of sediment found in the pipe, sometimes blocking more than 30% of the pipe flow. Because of the pipe velocities, the self-cleaning velocity is often not reached causing sediment deposition in the pipes.

The Gwynn's Falls Area is considered to be the western portion of the Low Level Sewershed. Significant and frequent evidence of surcharging was reflected in the flow monitoring data. This is consistent with what was reported in Section 5 – Hydraulic Modeling. This is also consistent with the sub-sewersheds that were selected for Smoke Testing due to high levels of RDII. There was also some evidence of SSOs and pipe bottlenecks in this area. Based on the flow monitoring installation reports, large amounts of sediment in this area did not appear to be an issue.

There was also some evidence of surcharging in the Locust Point Area. Meters LL27 and LL28 both show evidence of surcharging. This was likely the result of the Locust Point Pumping station at LL27 and the Locust Point and McComas Point Pumping Stations at LL28. The scattergraphs for LL28 also shows the existence of shifting debris and possibly an SSO. This is consistent with the information reported on the flow monitoring installation report.

The East Low Level Area that was not impacted by the EAPS showed isolated instances of surcharging with some bottlenecking at meter LL12 and LL06. Portions of this area are heavily industrial, also creating sporadic flow patterns.

The North Central meters exhibited isolated instances of data that appear to be somewhat sporadic. There was some evidence of surcharging at LL17, but it is unclear as to whether or not these data are reliable.

3.7.3 Correlation with Completed CCTV and Manhole Inspections

There is little correlation between the RDII and the manhole leaks indicated by the manhole inspections. The LL23 sub-basin had the lowest rate of RDII, but 35 percent of manholes in this sub-basin were reported to have leaks. The LL20 sub-basin, with the highest rate of RDII, had a similar percentage of leaking manholes (32 percent). The evidence of infiltration from the CCTV inspections did not seem to be correlated to the rate of RDII. For example, LL23 had the lowest rate of RDII and 26 percent of its pipes had evidence of infiltration from the CCTV inspections. Similarly, 21 percent of the pipes had infiltration defects in LL20, which had the highest rate of RDII. Despite comparing defects grouped by severity as well as all infiltration defects, no correlation was found between the infiltration defects and the sub-basins' RDII rankings. This lack of correlation is not unusual and could be attributed to the fact that the majority of I/I sources are typically located in the private sector. A number of studies throughout the nation indicate that as much as 75% of I/I sources are indeed in the private sector or outside the view of the camera.

3.7.4 RDII from Baltimore County

The Low Level Sewershed is not impacted by flows from Baltimore County.

3.7.5 Smoke Testing Recommendations

Flow monitoring data and CCTV inspection results indicate that significant inflow sources exist in the following basins, which were recommended for follow-up smoke testing:

LL14	LL37	LL45
LL19	LL41	LL46
LL35	LL42	
LL36	LL44	

3.8 Low Level Sewershed Infiltration and Inflow Evaluation Report

Attachment 3.8.1 contains the Low Level I/I Evaluation Report prepared by the Low Level Sewershed Consultant. The report contains site reports, scattergraphs, hydrographs, and Q to I scatterplots for every flow monitoring location.